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Patent  
Case No. U 0232-F02A

#### TITLE OF THE INVENTION

Interlaced Series Parallel Configuration for Metal Solvent Extraction Plants

#### CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of copending provisional  
5 application serial number 60/463,243, filed on April 16, 2003, the entire  
contents of which is incorporated herein by reference.

#### BACKGROUND OF THE INVENTION

Various metals can be recovered from their ores by leaching.  
Leaching is accomplished by contacting ore-containing rock with an aqueous  
10 acidic solution. A metal of choice can be obtained from a body of ore which  
contains a mixture of metals in addition to the desired metal. The leaching  
medium dissolves salts of the desired metal and other metals as it trickles  
through the ore, to provide an aqueous solution of the mixture of metal  
values. The metal values are usually leached with a sulfuric acid medium,  
15 providing an acidic aqueous solution, but can also be leached by ammonia  
to provide a basic aqueous solution.

The aqueous leaching solution is mixed in tanks with an extraction  
reagent which is dissolved in an organic solvent, e.g., a kerosene. The  
reagent includes an extractant chemical which forms a metal-extractant

complex with the desired metal ions in preference to ions of other metals.

The step of forming the complex is called the extraction or loading stage of the solvent extraction process. The nature of the extractant depends upon the metal to be extracted and the nature of the leach solution. For example,

5 zinc can be extracted with di-2-ethylhexylphosphoric acid, uranium using a tertiary fatty amine reagent such as ALAMINE® tertiary amine, cobalt as the chloride complex using a tertiary fatty amine reagent such as ALAMINE® tertiary amine, cobalt using an organo phosphonic acid or phosphinic acid, nickel using a carboxylic acid, molybdenum using a tertiary fatty amine  
10 reagent such as ALAMINE® tertiary amine. Copper can be extracted with an aldoxime such as 2-hydroxy-5-nonyl benzaldoxime, a ketoxime such as a 2-hydroxy-5-alkylphenyl ketoxime or combinations of aldoximes and ketoximes such as is described in U.S. patent 6,395,062, the entire contents of which are incorporated herein by reference and oximes in combinations with  
15 extractant and equilibrium modifiers such as is described in U.S. patents 6,231,784 and 6,177,055, the entire contents of each of which are incorporated herein by reference.

New and more economical methods of improving the extraction process are continuously being sought in order to lower costs and improve  
20 the quality of the metal produced.

#### BRIEF SUMMARY OF THE INVENTION

The present invention is an interlaced series parallel configuration for metal solvent extraction plants. The method is comprised of the steps of: (1) contacting an organic phase comprised of a water insoluble and water  
25 immiscible solvent solution of an extraction reagent formulation substantially

free of metal values with a first aqueous metal bearing solution to extract at least a portion of the metal into the organic phase to form a metal depleted aqueous raffinate solution and a first partially loaded organic phase wherein the first aqueous metal bearing solution is the raffinate from step (3); (2)

5 contacting the first partially loaded organic phase with a second aqueous metal bearing solution to form a metal depleted aqueous raffinate solution and a second partially loaded organic phase having a metal content greater than the first partially loaded organic phase; (3) contacting the second partially loaded organic phase with a third aqueous metal bearing solution to

10 form a partially metal depleted aqueous and a third partially loaded organic phase.

A modification of the process according to the invention is a triple interlaced series parallel configuration for metal solvent extraction plants. This method is comprised of the steps of: (1) contacting an organic phase

15 comprised of a water insoluble and water immiscible solvent solution of an extraction reagent formulation substantially free of metal values with a first aqueous metal bearing solution to extract at least a portion of the metal into the organic phase to form a metal depleted aqueous raffinate solution and a first partially loaded organic phase phase wherein the first aqueous metal

20 bearing solution is the raffinate from step (4); (2) contacting the first partially loaded organic phase with a second aqueous metal bearing solution to form a metal depleted aqueous raffinate solution and a second partially loaded organic phase having a metal content greater than the first partially loaded organic phase; (3) contacting the second partially loaded organic phase with

25 a third aqueous metal bearing solution to form a metal depleted aqueous

raffinate solution and a third partially loaded organic phase having a metal content greater than the second partially loaded organic phase; (4) contacting the third partially loaded organic phase with a fourth aqueous metal bearing solution to form a partially metal depleted aqueous and a  
5 fourth partially loaded organic phase.

#### BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

Figure 1 is a flow diagram of a conventional series parallel extraction configuration.

Figure 2 is a flow diagram of an interlaced series parallel extraction  
10 configuration.

Figure 3 is a flow diagram of a conventional series triple parallel extraction configuration.

Figure 4 is a flow diagram of an optimized interlaced series parallel special triple extraction configuration.

#### 15 DETAILED DESCRIPTION OF THE INVENTION

The process according to the invention can be best understood with reference to the figures. While the process according to the invention can be used in the extraction of any metal including, but not limited to, zinc, uranium, cobalt, nickel, and molybdenum, it will be described with reference  
20 to copper, the preferred embodiment.

As used herein the abbreviation PLS stands for a copper-rich aqueous leaching solution. The term "partially loaded organic phase" is an organic phase comprised of a water insoluble and water immiscible solvent solution of an extraction reagent formulation containing less than the  
25 maximum possible amount of metal values. The term "loaded organic phase"

is an organic phase comprised of a water insoluble and water immiscible solvent solution of an extraction reagent formulation containing the maximum possible amount of metal values. The extractant reagent is defined above and, in the case of copper extraction, can include equilibrium modifiers which

5 can be diesters of linear dicarboxylic acids such as linear alcohol esters of malonic, adipic, terephthalic acids. The term "stripped organic phase" is an organic phase comprised of a water insoluble and water immiscible solvent solution of an extraction reagent formulation substantially free of copper values. A stripped organic phase is one in which copper values have been

10 removed from a loaded or partially organic phase by contacting the loaded or partially organic phase with aqueous acid thereby transferring substantially all of the copper value from the organic phase to the aqueous phase or it can be fresh, unused organic phase. A raffinate is an aqueous solution which exits an extraction stage and has been at least partially depleted of

15 copper values by an organic phase.

Figure 1 depicts a flow diagram for a conventional series parallel extraction line where there is a fixed configuration and the extraction stages are in one row. The PLS is fed to two parallel-connected extraction stages, E1 and EP. The PLS is extracted in EP by stripped organic and the partially

20 loaded organic is sent to E2 wherein it extracts the raffinate from E1. In E1, the PLS is extracted and the aqueous from E1 is fed in series to E2 where it is extracted by the partially loaded organic from EP. The organic from E2 is fed to E1 where it extracts the PLS. The loaded organic from E1 is sent to stripping. The PLS is extracted by copper-free organic in EP and by partially

25 loaded organic in E1.

Figure 2 depicts a flow diagram of an interlaced series parallel extraction line where E2 and EP are juxtaposed. As in the conventional series parallel extraction line, the PLS is fed to two parallel-connected extraction stages, E1 and EP. In this configuration, the stripped organic is first contacted in E2 by the partially copper depleted aqueous from E1. This partially loaded organic then advances to the EP stage where it is contacted with a fresh volume of PLS and extracts additional copper. The organic phase then advances to E1 where it contacts a second stream of fresh PLS to form a fully loaded organic phase. The copper can be recovered from the fully loaded organic by stripping with aqueous acid. The strip aqueous solution resulting from the stripping contains substantially only copper. The pure copper metal can be recovered from the metal loaded stripping solution by electrowinning. This approach results in an overall higher recovery of copper than in the conventional series parallel configuration. This results primarily from the fact that the stripped organic which is a more efficient organic in terms of copper extraction contacts the partially copper depleted aqueous stream coming from E1. In a conventional circuit, this stripped organic first passes through the EP stage before entering E2 and extracts a significant amount of copper. It is not as efficient as a stripped organic in terms of achieving a low raffinate in the exiting aqueous raffinate stream.

The interlaced series parallel extraction configuration will typically achieve overall recoveries of from about 0.2 to about 5% absolute higher than a conventional series parallel configuration. For a 50,000 metric ton per year plant, a 1% improvement in recovery is equivalent to approximately \$1,500,000 in additional revenue at contemporary copper prices.

Figure 3 depicts a variation of the conventional series parallel extraction method which is a flow diagram of an series triple parallel extraction configuration having four extraction stages as opposed to three extraction stages depicted in Figure 1. In the series triple parallel extraction configuration, the stripped organic is first contacted in E4 by fresh PLS to form a first partially loaded organic and raffinate which is cycled back to the leaching operation. The first partially loaded organic from E4 is then contacted by fresh PLS in E3 to form a second partially loaded organic having a metal value greater than the first partially loaded organic and raffinate which is cycled back to the leaching operation. The second partially loaded organic from E3 is fed to E2 where it is contacted by raffinate from E1 which is formed by extraction of PLS by the third partially loaded organic from E2. The raffinate from the E2 extraction is cycled back to the leaching operation.

Figure 4 depicts a variation of the optimized triple series parallel method which is a flow diagram of an optimized triple series parallel extraction configuration having four extraction stages as opposed to three extraction stages in Figure 2. In the optimized triple series parallel extraction configuration, the stripped organic is first contacted in E4 by the partially copper depleted aqueous from E1. This partially loaded organic then advances to the E3 stage where it is contacted with a fresh volume of PLS and extracts additional copper. The organic phase then advances to E2 where it contacts a second stream of fresh PLS and extracts additional copper. The organic phase then advances to E1 where it contacts a second stream of fresh PLS to form a fully loaded organic phase.

The following examples are meant to illustrate but not to limit the invention.

### EXAMPLE 1

For comparison purposes, a trial was carried out at a copper solvent  
 5 extraction plant operating with a conventional series-parallel configuration.  
 The plant was carefully monitored for a period of time and then the circuit  
 was re-piped to operate with the interlaced series parallel configuration. The  
 operating conditions and overall copper recovery data for each circuit  
 configuration are summarized in the following Tables:

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#### EXTRACTION DATA FOR INTERLACED SERIES PARALLEL CONFIGURATION

	PLS	3.74 g/l Cu, pH 2.05
15	Total PLS flow	320 m <sup>3</sup> /h
	PLS flow to E1 (series)	180 m <sup>3</sup> /h
	PLS flow to EP (parallel)	140 m <sup>3</sup> /h
	Organic flow (whole circuit)	180 m <sup>3</sup> /h
	Reagent concentration	18.4 % (v/v)
20	E1 semi-raffinate	1.10 g/l Cu
	EP raffinate (parallel)	0.23 g/l Cu
	E2 raffinate (series)	0.09 g/l Cu
	Overall O/A Extraction	1/1
	O/A E1 stage (aq. recycle)	0.85/1
25	Spent electrolyte	31.1 g/l Cu, 175.0 g/l H <sub>2</sub> SO <sub>4</sub>
	Pregnant electrolyte	44.4 g/l Cu
	Series recovery	97.6 %
	Parallel recovery	93.8 %
	Combined recovery	95.9 %
30	Net copper transfer	0.347 g/l Cu/volume % extractant.



## COMPARATIVE EXAMPLE

### EXTRACTION DATA FOR CONVENTIONAL SERIES PARALLEL CONFIGURATION

5	PLS	3.74 g/l Cu, pH 2.12
	Total PLS flow	320 m <sup>3</sup> /h
	PLS flow to E1 (series)	140 m <sup>3</sup> /h
	PLS flow to EP (parallel)	180 m <sup>3</sup> /h
	Organic flow (whole circuit)	180 m <sup>3</sup> /h
10	Reagent concentration	18.4 % (v/v)
	E1 semi-raffinate	1.30 g/l Cu
	E2 raffinate (series)	0.32 g/l Cu
	EP raffinate (parallel)	0.29 g/l Cu
	Overall O/A Extraction	1/1
15	O/A E1 stage (aq. recycle)	0.85/1
	Spent electrolyte	30.0 g/l Cu, 180.3 g/l H <sub>2</sub> SO <sub>4</sub>
	Pregnant electrolyte	43.5 g/l Cu
	Series recovery	91.4 %
	Parallel recovery	92.2 %
20	Combined recovery	91.9 %
	Net copper transfer	0.332 g/l Cu/volume % extractant

The plant organic was used in both cases. The majority of the extractant present in the organic was LIX® 984N, a trademark product of

25 Cognis Corporation, Cincinnati, Ohio.

While operating in the interlaced series parallel configuration, an additional 4% overall recovery of copper was achieved as compared to operating with the conventional series parallel configuration.